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Dairy Herd Improvement Letter

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NATIONAL COOPERATIVE
DAIRY HERD IMPROVEMENT
PROGRAM
A dairy recordkeeping plan
for every herd

CURRENT SERIAL RECORDS

- Computing Lactation Records From Sample-Day Production
- Adjusting Records From Three-Times-a-Day to Two-Times-a-Day Milking Basis
- Factors for Improving Accuracy of Estimates of Test-Interval Yield
- Factors for Estimating Sample-Day Yield in AM-PM Sampling Plans

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Dairy Herd Improvement Letter

COMPUTING LACTATION RECORDS FROM SAMPLE-DAY PRODUCTION

By G. R. Wiggans[1] and M. Grossman[1 2]

Lactation production is usually estimated from production on a few days during lactation because it is not economical to record production information every day. The day when milk production is weighed and sampled is called the sample day or test day. Sample day is preferred because test day may refer to the day the milk sample is tested for butterfat percentage.

The lactation period is divided into test intervals at the sample days. Each interval extends from the day following the previous sample day through the current sample day. The production between sample days is estimated from production on the previous and current sample days. The Official Dairy Herd Improvement Rules[3] state:

> Production credits for the first half of the test interval are calculated from the previous test day information, and production credits for the second half of the test interval are based on the current test day information. The totals for the two portions of the test interval are added to obtain the test interval totals.

This procedure gives equal weight to the previous and current sample-day productions. The previous sample day is before the test interval; therefore, production on the previous sample day should not receive as much weight as the current sample-day production that is included in the interval. Test-interval production can be represented as the sum of productions for each day in the interval. The daily production is estimated by assuming a uniform daily change in production from the previous to the current sample day. A modification of the method of computing test-interval credits employing this assumption follows:

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[3] Coordinating Group for the NCDHIP. Official Dairy Herd Improvement Rules, p. 16. 1977.

Calculation of Test-Interval Production

Let the length of the test interval (LI) be

$$LI = (DIM_n - DIM_{n-1})$$

where DIM_n is the days in milk at the nth sample. Let the daily change in production during the test interval (DC) be

$$DC = (P_n - P_{n-1})/LI$$

where P_n is the production on the nth sample day. The production for a test interval (PN) is computed as follows:

$$\begin{aligned} PN &= (P_{n-1}+DC) + [P_{n-1}+2(DC)] + \cdots \\ &\quad + [P_{n-1} + (LI-1)(DC)] + P_n \qquad (1) \\ &= (LI-1)(P_{n-1}) + \tfrac{1}{2}(LI-1)(LI)(DC) + P_n \qquad (2) \\ &= (LI-1)[\tfrac{1}{2}(P_{n-1}+P_n)] + P_n \qquad (3) \\ &= \tfrac{1}{2}(LI-1)(P_{n-1}) + \tfrac{1}{2}(LI+1)(P_n) \qquad (4) \\ &= \tfrac{1}{2}LI(P_{n-1}) + \tfrac{1}{2}LI(P_n) + \tfrac{1}{2}(P_n - P_{n-1}) \qquad (5) \end{aligned}$$

Equation (1) shows the estimates of production for each day in the interval. Each differs from the previous day's estimate by DC. Equation (3), (4), or (5) could be used to compute the production credit for the test interval. Equation (3) shows that the average production of the 2 sample days is used to estimate the production for all days between. The 2 sample days receive equal weight in estimating production on the days between sample days. The known production on the current sample day is then added to compute the test-interval credit. Equation (4) indicates that the current sample-day production is used for 1 day more than the previous sample-day production. In equation (5), the first two terms give production credits by the official DHI rules; the third term is the effect of the modification. Equation (3) is illustrated for milk production in the fifth test interval of the lactation record in table 1:

$$PN = [34(58.4 + 52.6)/2] + 52.6 = 1{,}939.6$$

Computation of test-interval credits for milk-component yield is the same as for milk yield. Milk-component yield for each sample day is calculated by multiplying the sample-day percentage by the sample-day milk production. In AM-PM testing plans, production at a single milking is used to estimate daily production by following the procedure on page 26. The test-interval production is computed from the estimate as though it were the measured daily yield.

Calculation of a 305-Day Record

Production through 305 days in milk is the standard record. Because test intervals rarely end at 305 days, two procedures to compute production credits for a test interval that ends at 305 days are provided. One procedure estimates the daily production with

Table 1.--Example of computing milk production credits for a first lactation record

Test interval (n)	Days in milk (DIM)	Sample-day milk (P_n)	Length of test interval (LI)	$\frac{(P_{n-1}+P_n)}{2}$	Adjustment factor	Test-interval credit
	Number	Lb	Days	Lb		Lb
1------	9	45.2	9	[1]45.2	0.74	301.0
2------	34	61.8	25	53.5	1.04	1,399.6
3------	68	60.2	34	61.0	1.01	2,093.9
4------	100	58.4	32	59.3	---	1,896.7
5------	135	52.6	35	55.5	---	1,939.6
6------	160	55.4	25	54.0	---	1,351.4
7------	200	50.8	40	53.1	---	2,121.7
8------	235	45.2	35	48.0	---	1,677.2
9------	275	38.4	40	41.8	---	1,668.6
10------	310	30.9	35	34.7	---	1,209.0
Last----	320	(Dry before next test)	10	[1]30.9	.99	305.9
Total-	---	---	---	---	---	15,965.0

[1] At the start and end of the lactation, there is a sample day at only one end of the interval; therefore, no averaging is done.

the daily change and is used when there is a sample day with milk production after 305 days. These estimates are totaled over the period ending at 305 days. The length of the interval to 305 days (*LI*) is

$$LI = 305 - DIM_{n-1}$$

To compute *DC*, however, the number of days from the previous to the current sample day must be used:

$$DC = (P_n - P_{n-1})/(DIM_n - DIM_{n-1})$$

Production credit is computed as follows:

$$\begin{aligned} PN &= (P_{n-1} + DC) + [P_{n-1} + 2(DC)] + \ldots \\ &\quad + [P_{n-1} + LI(DC)] \\ &= LI(P_{n-1}) + \tfrac{1}{2}LI(LI+1)(DC) \\ &= LI[P_{n-1} + \tfrac{1}{2}(LI+1)(DC)] \end{aligned}$$

For the lactation in table 1, production for the interval to 305 days is computed as follows:

$$LI = 305 - 275 = 30$$

$$DC = (30.9 - 38.4)/(310 - 275) = -0.214$$

$$PN = 30[38.4 + (31/2)(-0.214)] = 1{,}052.5$$

Another procedure is used when there is no sample day with milk production after 305 days. The daily change cannot be computed; therefore, the adjustment for the interval from the last sample to the end of the record is used as described on page 5.

Adjustments to Test-Interval Production Credits

A typical lactation curve has an early period of rapid increase to peak production followed by a long period of slow decline. To estimate production accurately requires accounting for the location of sample days on the lactation curve. Adjustment must be made to the interval from freshening through the first sample day and to any later interval beginning before the cow has milked 40 days (an interval that includes the peak of production). Adjustment is also made to the interval from the last sample day to the end of the record. A discussion of the development of these adjustments begins on page 9; an illustration of their use follows.

Interval from calving through first sample.--A cow's milk weight is not recorded before the sixth day after calving; therefore, the first test interval must be at least 7 days (counting the fresh date). An interval of 6 days is possible, however, with AM-PM testing. The first interval should be no more than 45 days. (A test interval of 46-75 days requires special approval.) This first interval covers a period of rapid increase in production and requires adjustment. Because there is no previous sample-day production, the credit is computed from the current sample day alone:

$$PN = DIM_1(P_1)(F)$$

where F is the adjustment factor and P_1 is the first sample-day production at DIM_1 days in milk. In table 1, the credit for the first interval is computed as

$$PN = 9(45.2)(0.74) = 301.0 .$$

Intervals after the first that begin prior to 40 days of lactation.--Because daily yield is expected to peak by 40 days in lactation, most actual daily yields are above their estimates for an interval that includes the peak. In figure 1, the peak is illustrated by the arc connecting the second and third sample-day productions. To account for the peak, the unadjusted test-interval credit is multiplied by a factor as follows:

$$PN = \{(LI-1)[\tfrac{1}{2}(P_n+P_{n-1})] + P_n\}F$$

In table 1, the credit for the second interval is

$$PN = [24(53.5) + 61.8]1.04 = 1,399.6$$

Interval from last sample to end of lactation record.--Because there is no sample-day production at the end of the period, a daily change cannot be computed. The production credit is computed as the length of the interval (LI) times the last sample-day production times an adjustment factor; in this case, LI is the days in milk from the last sample day to the end of the record:

$$PN = LI(P_n)(F)$$

In the example,

$$PN = 10(30.9)(0.99) = 305.9$$

This procedure applies to the calculation of a 305-day yield when there is no sample day after 305 days.

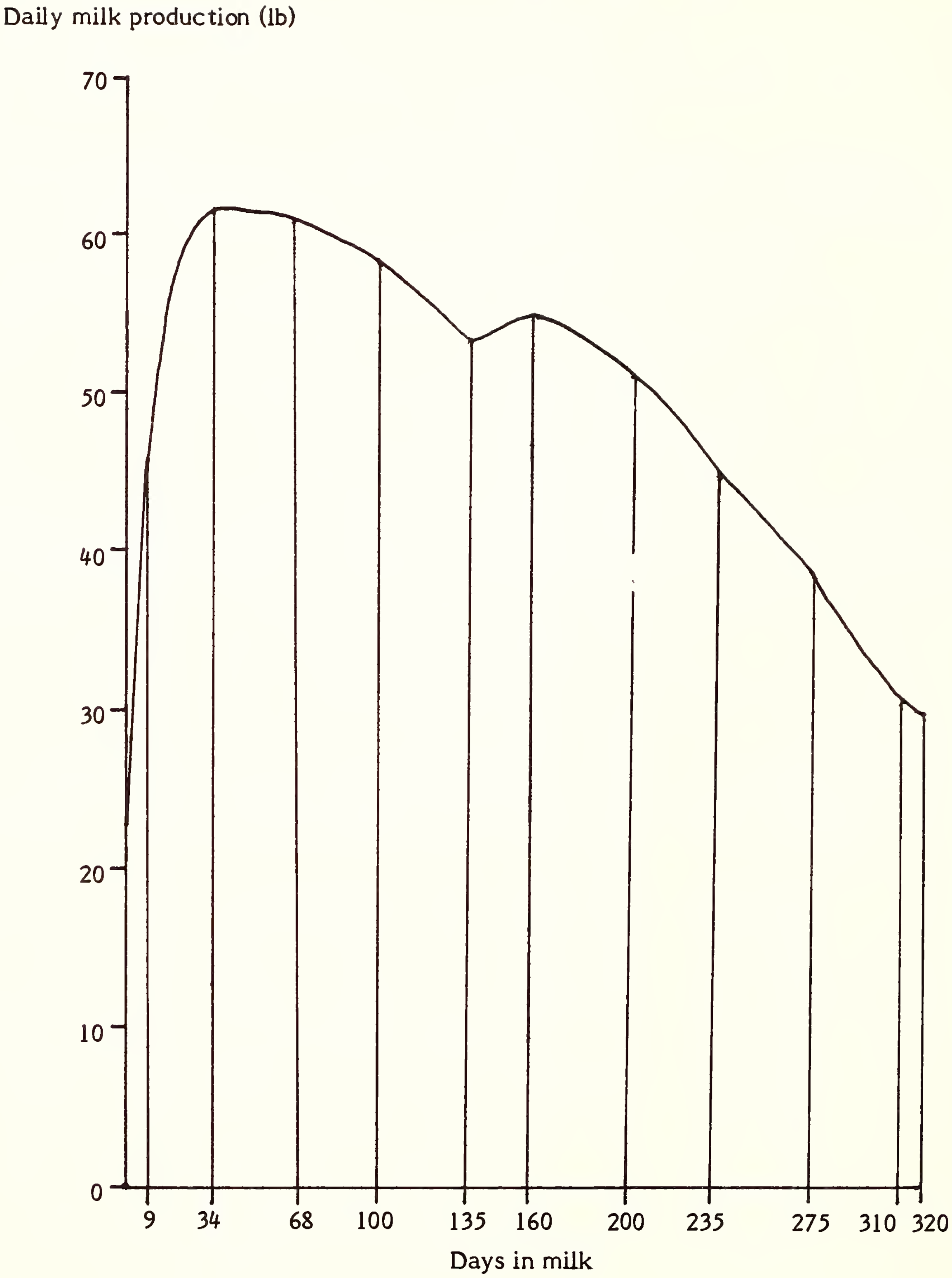

Figure 1.--Lactation curve of production in table 1.

ADJUSTING RECORDS FROM THREE-TIMES-A-DAY
TO TWO-TIMES-A-DAY MILKING BASIS

By G. R. Wiggans[1] and M. Grossman[1] [2]

Milking cows three times a day (3X) results in increased production compared with milking two times a day (2X). When evaluating genetic merit, it is necessary to remove this environmental effect so that cows milked 3X can be fairly compared with cows milked 2X. Frequently cows are milked 3X for only part of the lactation. Previous Letters[3] [4] have presented tables of factors to adjust 3X records to a 2X basis for different numbers of days milked 3X. These tables were appropriate for cows whose records actually reached 305 days and were based on the following relative increases (*RI*) (the increases due to 3X milking divided by the 2X production):

Age (years)	Relative increase
2	0.20
3	.17
4	.15

To appropriately adjust 3X records of all lengths, use the proportion of days milked 3X (DIM_{3X}) to the total days in milk (*DIM*) times the relative increase as follows:

$$REC_{2X} = REC_{3X}/(1 + RI(DIM_{3X}/DIM))$$

where REC_{2X} is the record adjusted to a 2X equivalent and REC_{3X} is the 3X record. In the special case when 3X milking is for the entire record, the formula simplifies to

$$REC_{2X} = REC_{3X}/(1+RI)$$

Computing days 3X.--The days milked 3X should reflect that portion of the lactation record that was computed from sample days with 3X milking. If the cow in the example on page 3 were milked 3X for the first 3 sample days (days 9, 34, and 68), her days 3X would be 68 plus half the number of days to the following sample day (31/2), giving 83.5 days. Half days should be rounded to the even day; therefore, this cow would have 84 days 3X.

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[3] Kendrick, J. F. Standardizing Dairy Herd Improvement Association records in proving sires. U.S. Dept. Agr. ARS-52-1, 14 pp. 1955.

[4] U.S. Department of Agriculture. Reducing records to a twice-a-day milking basis. Dairy Herd Improvement Letter 46 (1), U.S. Dept. Agr. ARS 44-239, 4 pp. 1972.

Projecting 3X records.--Prior to the new projection factors,[5] all adjustments to lactation records were multiplicative so order was unimportant. With the new projection factors, the sequence of adjustments affects the adjusted record because the projection, based on the last sample-day production, is additive. Projection factors were developed from 2X records so 3X records must be adjusted to a 2X basis before projection.

When the days milked 3X are less than the days in milk, 2X is assumed for the last sample day. The partial-record milk and fat yields are adjusted to a 2X basis, and the record is projected. When the days 3X are equal to the days in milk, the last sample-day production and the partial-record production are adjusted with the formula for a record with 3X milking during the entire record. The fat percentage is not adjusted.

Consider a record in progress for the cow in the example with 68 days in milk, 60.2 lb on the third sample day, and 3,794.5 lb of milk. Assume 3X milking for the entire record. Then,

$$REC_{2x} = 3{,}794.5/(1 + 0.2) = 3{,}794.5/1.2 = 3{,}162.1$$

$$P_{3_{2x}} = 60.2/1.2 = 50.2$$

where $P_{3_{2x}}$ is the third sample-day production adjusted to a 2X equivalent.

If the record in progress were at 100 days with 3X milking for the first 3 sample days but not for the last sample day, production at day 100 would not be adjusted. Days 3X would be 84 as computed above. The adjusted partial record would be

$$REC_{2x} = 5{,}691.2/\left(1 + 0.2(84/100)\right) = 5{,}691.2/1.168 = 4{,}872.6$$

Factors affecting adjustment.--This method of adjusting 3X records does not consider when the 3X milking occurs during the lactation. The effect of milking 3X may extend beyond the period milked 3X and may not be a constant proportion of daily production, i.e., the advantage due to 3X milking may occur largely in late lactation. Information on the advantage of 3X milking on a daily basis might make possible more accurate adjustment for frequency of milking.

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[5] Wiggans, G. R., and Powell, R. L. Projection factors for milk and fat lactation records. U.S. Dept. Agr. Dairy Herd Improvement Letter, Vol. 56 (1), 15 pp. 1980.

FACTORS FOR IMPROVING ACCURACY OF ESTIMATES OF TEST-INTERVAL YIELD

By G. E. Shook,[1] L. P. Johnson,[2] and F. N. Dickinson[3]

Various methods of calculating lactation credits have been used in the National Cooperative Dairy Herd Improvement Program (NCDHIP). The Centering Date Method (CDM) was used for many years until the late 1960's. CDM presumed testing at monthly intervals within 3 days of the centering date. In practice, monthly testing was not always possible, and sample day most often followed the centering date, causing lactation credits to be underestimated. In 1969, the Test Interval Method (TIM) was adopted for official testing. TIM solved the problem of underestimation by calculating credits for test intervals, i.e., the period from the day following the previous sample day through the current sample day, rather than monthly periods. Test intervals need not be monthly although official rules do specify a minimum of 10 sample days per year and maximum test intervals of 45 days (or 75 days if approved).[4]

Sargent et al.[5] presented a thorough comparison of these methods. Inaccuracies inherent in CDM and TIM are detailed in the following section. Everett et al.[6] reported that the bias in estimating lactation yield varied from zero to 200 lb, depending on the day of lactation when the sample day occurs. They found that over 80 percent of this bias occurred in estimating yield in the first month of lactation. In a review of accuracy of DHI sampling procedures, McDaniel[7] concluded that "more accurate and precise methods (of estimating yield), such as ones cognizant of the stage of lactation at first test, should be encouraged."

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[3] Chief, Animal Improvement Programs Laboratory, Animal Science Institute, Beltsville Agricultural Research Center, Beltsville, Md. 20705.

[4] Coordinating Group for the NCDHIP. Official Dairy Herd Improvement Rules. 1977.

[5] Sargent, F. D., Lytton, V. H., and Wall, O. G., Jr. Test interval method of calculating Dairy Herd Improvement Association records. J. Dairy Sci. 51: 170-179. 1968.

[6] Everett, R. W., Carter, H. W., and Burke, J. D. Evaluation of the Dairy Herd Improvement Association record system. J. Dairy Sci. 51: 153-162. 1968.

[7] McDaniel, B. T. Accuracy of sampling procedures for estimating lactation yields: A review. J. Dairy Sci. 52: 1742-1761. 1969.

The purpose of this article is to describe adjustments to test-interval yield. The objective of these adjustments is to reduce errors in estimating yield in NCDHIP testing.

The Problem

Procedures to develop test-interval adjustments depend on the shape of an average lactation curve and the calculation of test-interval production. Figure 1 shows average lactation curves for cows in first and later lactations. Production increases rapidly after calving to a peak at about 40 days in milk. Thereafter, daily yield declines at a nearly linear rate, i.e., equal decreases each day. Estimation of test-interval production is illustrated for four test intervals in figure 2.

In the first test interval, production is computed as the number of days from calving to the first sample times the sample yield. In figure 2, the first sample was on day 20 and the yield on that day was 65 lb. The cow is credited with (20 days)(65 lb/day) = 1,300 lb. Since the highest yield of any day in the test period occurs on the sample day, the procedure clearly overestimates actual production.

The second test-interval yield is computed as average production on the first and second sample days times the number of days between samples plus the second sample-day production (applying the modification discussed in the first article). In the illustration, the second test interval includes days 21 through 50 or a total of 30 days. The milk yield on day 50 was 67 lb, making 66 lb the average yield for the first 2 sample days. The test-interval credit is (29 days)(66 lb/day) + 67 lb = 1,981 lb. This is clearly less than actual production, because the actual production on most days was above the estimated production for those days.

A mid-lactation test interval is illustrated for the interval from day 151 through day 175. Credits here are computed as for the second test interval. Yields for the 2 sample days are 50 and 46 lb for an average of 48 lb. The test-interval yield is (24 days)(48 lb/day) + 46 lb = 1,198 lb, which is an accurate estimate of the actual yield because the average yield of the 2 sample days is the same as the average yield of all the days between.

For the period from the last sample day through the end of lactation, the yield is estimated as days through the end of the interval times yield on the last sample day. In figure 2, yield on day 280 is 32 lb and test-interval credit is (25 days)(32 lb/day) = 800 lb. This obviously overestimates production, because the credit was based on the day of highest production during the period.

In summary, three parts of the lactation are given improper credit: (1) Interval from calving to first sample, (2) intervals that span the lactation peak, and (3) interval after the last sample. The amount of error in these intervals varies according to the days in milk at the first sample and the number of days between samples.

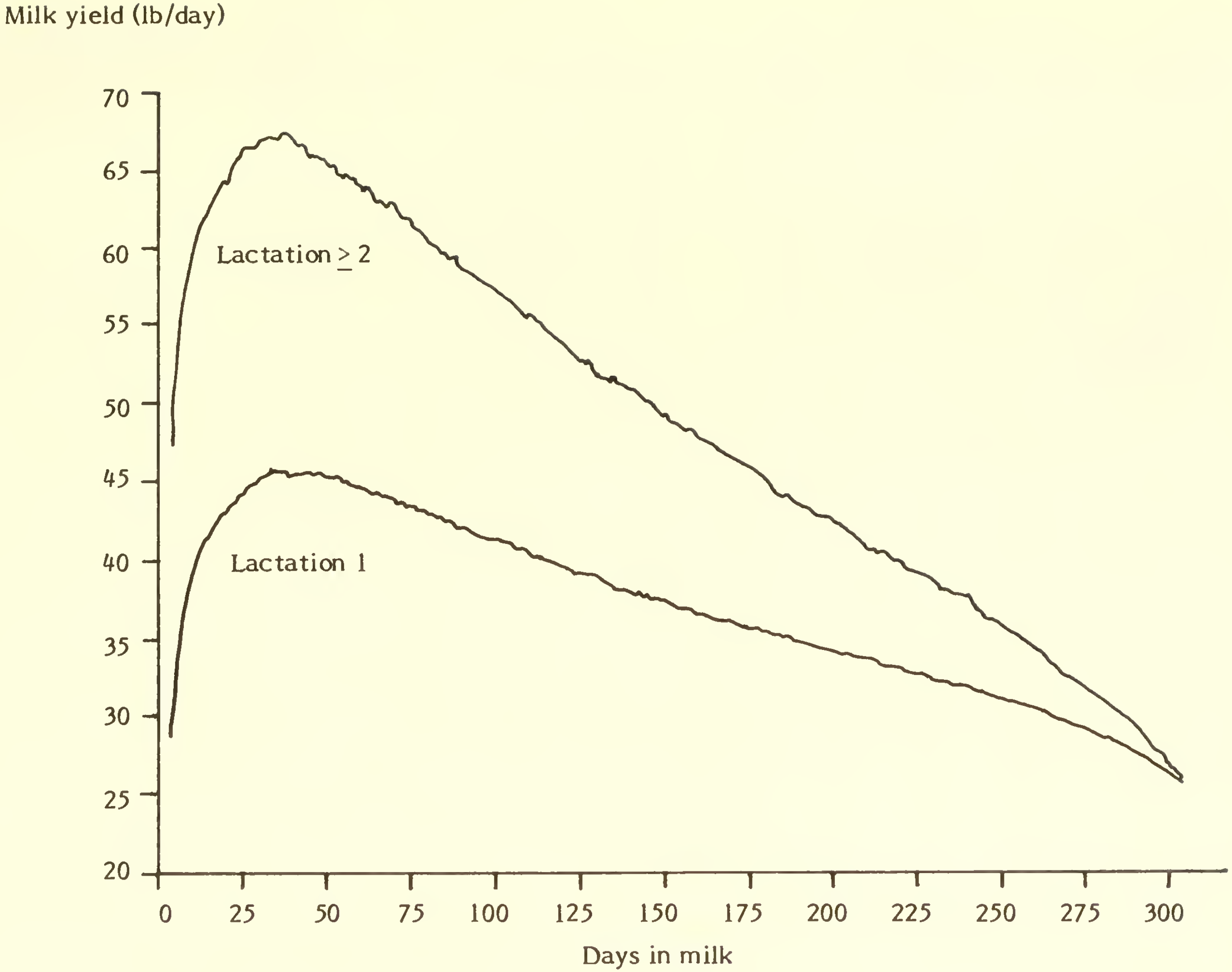

Figure 1.--Average lactation curves for cows in first and later lactations.

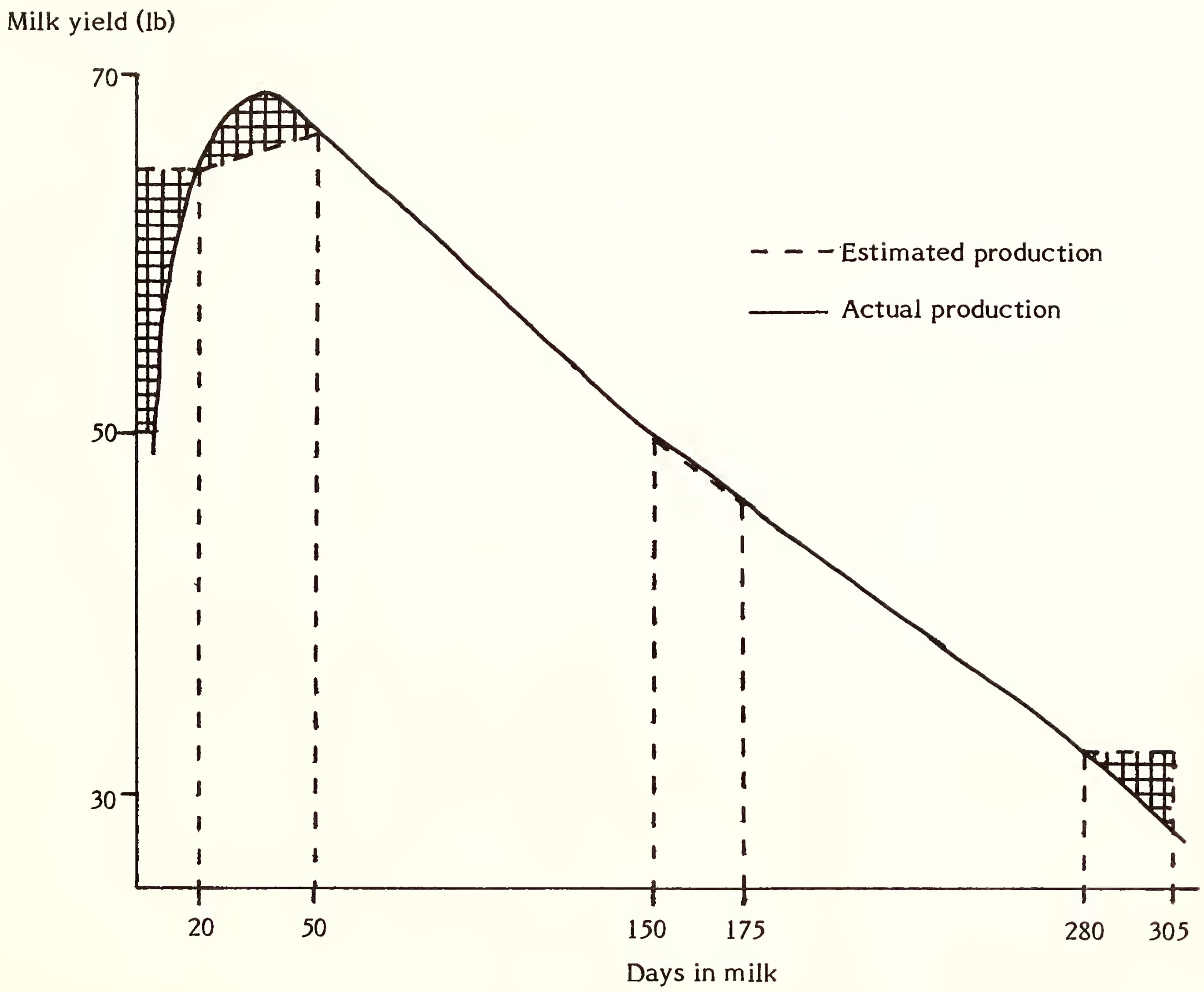

Figure 2.--Estimation of test-interval yield by test-interval method. Area under lactation curve represents actual yield; areas enclosed by dashed lines represent estimated yield; and cross-hatched areas represent amount by which TIM is biased.

Data

Data used in developing adjustment factors were lactations with 305 daily milk weights and yields of fat, protein, and solids-not-fat (SNF). Milk yields were available for 1,210 lactations, fat and protein yields for 151 lactations, and SNF yields for 78 lactations. Location of the herds and distribution of the records by breed are described on page 25.

Study of the data by statistical methods and by subjective comparison of alternative sets of factors led to these conclusions:

(1) Separate factors are required for each trait—milk, fat, protein, and SNF yield.

(2) The same factors can be used for all breeds. Breed differences in most instances were small or nonexistent.

(3) Separate factors are required for first lactation, but succeeding lactations may be treated as a group. The major difference in shape of the lactation curve occurs between the first and second lactations. Although differences do exist among second, third, and later lactations, they are not large. Too few lactations were available to accurately develop separate factors for each lactation after the first.

(4) The same factors apply to all seasons of the year. Although seasonal influences on lactation curves are real, the effect on these factors was not great.

Development of Factors

Test-interval adjustment factors were developed from average lactation curves for first lactations and for second and later lactations. The general principle used in developing these factors was that a factor is equal to the ratio of actual test-interval yield to yield estimated by TIM. In other words, a factor is the average daily yield throughout the test interval divided by the (average) yield on the sample day(s). The details of the development are on page 20. Factors vary with the days in milk when the test interval begins and with the number of days in the test interval. Because the first test interval always begins with calving date, factors for the first interval vary only with the number of days in the interval.

Lactation curves of milk yield for those records with fat, protein, and SNF were different from lactation curves for the larger data set with only milk yield available. Lactation curves for yields of the components were constructed from the average percentage of the component in the small data set and the average milk yield in the large data set. Factors for the components were developed from these derived lactations.

Applying the Factors

Factors are presented for the yields of milk, fat, protein, and SNF in tables 1-3. Average percentage of a yield component for a test interval may be computed from the adjusted component yield and adjusted milk yield. Separate factors are presented for the three parts of the lactation curve that require adjustment. Each will be described in turn. Refer to Official Dairy Herd Improvement Rules[4] regarding procedures for missing or abnormal tests or lost samples.

Table 1.--Factors for adjusting first test-interval yields

Day of first sample[1]	Lactation 1				Lactation ≥ 2			
	Milk	Fat	Protein	SNF	Milk	Fat	Protein	SNF
6	0.71	0.69	0.70	0.68	0.74	0.76	0.76	0.73
7	.72	.71	.73	.70	.75	.78	.79	.75
8	.73	.74	.76	.72	.76	.80	.81	.76
9-10	.74	.76	.79	.74	.77	.82	.84	.78
11	.75	.79	.81	.76	.78	.84	.87	.80
12-13	.76	.81	.83	.77	.79	.86	.89	.81
14-15	.77	.83	.86	.79	.80	.87	.91	.83
16-17	.78	.85	.88	.81	.81	.89	.93	.84
18-19	.79	.87	.89	.82	.82	.90	.94	.85
20-21	.80	.89	.90	.83	.83	.92	.95	.86
22-23	.81	.90	.91	.84	.84	.93	.96	.87
24-25	.82	.91	.92	.85	.85	.94	.97	.88
26-27	.83	.92	.92	.86	.86	.95	.97	.89
28-30	.84	.93	.93	.87	.87	.96	.98	.90
31-33	.85	.94	.93	.87	.88	.97	.98	.91
34-35	.86	.95	.93	.88	.89	.98	.99	.91
36-38	.87	.95	.94	.89	.90	.99	.99	.92
39-41	.88	.96	.94	.89	.91	1.00	.99	.93
42-44	.89	.96	.94	.90	.92	1.01	.99	.93
45-47	.90	.97	.94	.91	.93	1.02	.99	.94
48-50	.91	.97	.94	.92	.94	1.03	.99	.95
51-54	.92	.98	.94	.92	.95	1.03	.99	.96
55-57	.93	.98	.94	.93	.96	1.04	.99	.97
58-61	.94	.99	.94	.93	.97	1.05	1.00	.98
62-64	.95	.99	.95	.94	.98	1.06	1.00	.97
65-68	.96	1.00	.95	.95	.99	1.07	1.01	.99
69-72	.97	1.00	.96	.96	1.00	1.08	1.02	1.00
73-75	.98	1.01	.97	.97	1.01	1.09	1.03	1.02
>75	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

[1] Days in milk.

Table 2.--Factors for adjusting yields for test intervals at peak of lactation

Day of previous sample[1]	Component	Days in test interval							
		1-10	11-19	20-28	29-37	38-46	47-55	56-64	65-75
					Lactation 1				
6-7	Milk	1.04	1.06	1.08	1.09	1.11	1.13	1.15	1.16
	Fat	1.02	1.03	1.03	1.04	1.05	1.06	1.05	1.05
	Protein	1.02	1.04	1.02	1.03	1.03	1.04	1.04	1.04
	SNF	1.04	1.06	1.07	1.08	1.09	1.11	1.11	1.13
8-10	Milk	1.02	1.03	1.04	1.05	1.07	1.08	1.09	1.10
	Fat	1.02	1.02	1.03	1.03	1.03	1.04	1.03	1.03
	Protein	1.01	1.01	1.00	1.00	1.01	1.01	1.01	1.01
	SNF	1.02	1.03	1.03	1.04	1.05	1.06	1.07	1.08
11-13	Milk	1.01	1.02	1.03	1.04	1.05	1.05	1.06	1.07
	Fat	1.01	1.01	1.01	1.01	1.02	1.02	1.01	1.01
	Protein	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.01
	SNF	1.01	1.01	1.01	1.03	1.03	1.04	1.05	1.05
14-22	Milk	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.05
	Fat	1.01	1.01	1.01	1.01	1.02	1.01	1.01	1.01
	Protein	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.02
	SNF	1.00	1.00	1.01	1.02	1.02	1.03	1.03	1.04
23-31	Milk	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03
	Fat	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
	Protein	1.01	1.01	1.02	1.02	1.02	1.02	1.03	1.03
	SNF	1.00	1.01	1.01	1.02	1.02	1.02	1.03	1.03
32-39	Milk	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02
	Fat	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Protein	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01
	SNF	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.01
					Lactation ≥ 2				
6-7	Milk	1.02	1.04	1.05	1.07	1.08	1.10	1.12	1.13
	Fat	1.01	1.01	1.01	1.02	1.03	1.03	1.03	1.03
	Protein	1.02	1.01	1.00	1.00	1.00	1.00	1.00	1.01
	SNF	1.02	1.04	1.04	1.06	1.07	1.08	1.08	1.09
8-10	Milk	1.01	1.03	1.04	1.05	1.06	1.07	1.08	1.09
	Fat	1.00	1.00	1.01	1.02	1.02	1.02	1.02	1.02
	Protein	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	SNF	1.01	1.02	1.02	1.03	1.04	1.05	1.05	1.06
11-13	Milk	1.01	1.02	1.03	1.04	1.04	1.05	1.06	1.07
	Fat	1.00	1.00	1.01	1.02	1.02	1.02	1.01	1.02
	Protein	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	SNF	1.01	1.01	1.01	1.02	1.03	1.03	1.04	1.05
14-22	Milk	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.05
	Fat	1.00	1.00	1.01	1.02	1.02	1.01	1.01	1.01
	Protein	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.01
	SNF	1.00	1.00	1.01	1.02	1.02	1.02	1.03	1.03
23-31	Milk	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03
	Fat	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Protein	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02
	SNF	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.02
32-39	Milk	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.02
	Fat	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Protein	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01
	SNF	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01

---

[1] Days in milk.

Table 3.--Factors for adjusting yields for test intervals after last sample day

Day of last sample[1]	Component	Days in test interval						
		5-14	15-24	25-34	35-44	45-54	55-64	65-75
					Lactation 1			
40-159	Milk	0.99	0.98	0.97	0.97	0.96	0.95	0.94
	Fat	.99	.99	.98	.97	.97	.96	.95
	Protein	.99	.99	.98	.98	.97	.96	.96
	SNF	.99	.99	.98	.97	.96	.96	.95
160-249	Milk	.99	.98	.97	.96	.95	.94	.93
	Fat	.99	.98	.98	.97	.96	.95	.94
	Protein	.99	.99	.98	.97	.96	.96	.95
	SNF	.99	.98	.97	.96	.95	.95	.94
250-305	Milk	.99	.97	.96	.95	.94	.92	.91
	Fat	.99	.98	.97	.96	.95	.94	.93
	Protein	.99	.98	.98	.97	.96	.95	.94
	SNF	.99	.98	.97	.96	.95	.94	.93
					Lactation $\geq$ 2			
40-129	Milk	.99	.97	.96	.95	.94	.92	.91
	Fat	.99	.98	.97	.95	.94	.93	.92
	Protein	.99	.98	.97	.95	.94	.93	.92
	SNF	.99	.98	.96	.95	.94	.93	.91
130-184	Milk	.99	.97	.96	.94	.93	.91	.90
	Fat	.99	.97	.96	.95	.93	.92	.91
	Protein	.99	.97	.96	.95	.93	.92	.91
	SNF	.99	.97	.96	.94	.93	.91	.90
185-224	Milk	.98	.96	.95	.93	.91	.89	.88
	Fat	.98	.97	.95	.94	.92	.91	.89
	Protein	.98	.97	.95	.94	.92	.91	.89
	SNF	.98	.97	.95	.93	.91	.90	.88
225-254	Milk	.98	.96	.94	.92	.90	.88	.86
	Fat	.98	.97	.95	.93	.91	.90	.88
	Protein	.98	.97	.95	.93	.91	.90	.88
	SNF	.98	.96	.94	.92	.90	.88	.86
255-279	Milk	.98	.96	.93	.91	.89	.87	.84
	Fat	.98	.96	.94	.92	.91	.89	.87
	Protein	.98	.96	.94	.92	.90	.89	.87
	SNF	.98	.96	.94	.91	.89	.87	.85
280-305	Milk	.97	.95	.92	.90	.87	.85	.82
	Fat	.98	.96	.94	.92	.90	.87	.85
	Protein	.98	.96	.94	.92	.89	.87	.85
	SNF	.98	.95	.93	.90	.88	.86	.83

[1] Days in milk.

Interval from calving to first sample day.--Factors listed in table 1 are used to compute yield for the period from calving to the first sample day. Factors are selected from the table according to lactation number and the day of lactation at the first sample day. Test-interval yield is computed as the product of days in the test interval, first sample-day yield, and factor. An example is on page 4.

Most factors for the first interval are less than 1.0 because average daily yield during the interval is less than the yield on the first sample day. TIM generally overestimates test-interval production in this period so the factors are less than 1.0.

Intervals around the lactation peak.--The factors in table 2 apply to any test interval after the first one and beginning before day 40. In most cases, this will be the second test interval. In unusual cases where a surprise test is conducted near a regular test, the third test interval may also require adjustment by these factors. If the first sample day occurs after the 40th day of lactation, the lactation peak is included in the first test interval and no adjustment is needed in the second interval.

Factors are selected from table 2 according to lactation number, days in milk at the previous sample day, and days in the test interval. Test-interval yield is the factor times the production as computed on page 2.

Factors in table 2 are greater than or equal to 1.0 because TIM generally underestimates yield in this period. Average daily production is greater than average sample-day production in this part of the lactation.

Interval after last sample day.—Factors for the last test interval are in table 3. If the last sample day occurred before day 40, no adjustment is made. When the last sample day is after day 305, factors for day 305 should be used. If the interval is fewer than 5 days, no adjustment is needed. The factors in table 3 should be used for computing 305-day yield when there is no sample day on or after day 305 and the lactation is longer than 305 days. Note that the factor to compute 305-day yield may differ from the factor to compute complete lactation yield.

Factors are selected from table 3 according to lactation number, days in milk at the last sample day, and days in the test interval. The test-interval yield is the product of days in the interval, last sample-day yield, and factor.

As with the first test interval, the factors for the last interval are less than 1.0 because TIM overestimates yield after the last sample day.

Bias and sampling error.—Actual production was computed from daily milk weights for all 1,210 lactations in this study. NCDHIP sampling of these lactations was simulated by randomly choosing sample days at intervals that averaged 30 days and ranged from 26 to 34 days. Yield was estimated with and without the test-interval adjustments for each test interval. Estimated lactation yield is the total of the test-interval estimates. The actual yields were compared with these estimates.

Bias was computed as the average estimated yield minus the average actual yield. Bias measures the average amount by which the sampling procedure overestimates or underestimates actual production. Sampling error measures the scatter of individual errors around bias.

TIM overestimates the actual yield in the first test interval (fig. 2). The critical problem is that the amount of overestimation varies with the day of first sample (table 4). For example, TIM, on the average, credits a first lactation cow sampled on day 36 with 104 lb more milk than if she had been sampled on day 12. The test-interval adjustment reduces these biases to near zero.

Bias and sampling error for potentially biased test intervals are shown with and without adjustment of test-interval yield in table 5. The most serious bias is found in the first test interval, and this bias also appears in the lactation yield. Test-interval adjustments effectively reduce bias and sampling error in estimates of test-interval yield.

Percentage reduction in sampling variance (square of sampling error) due to use of the adjustment factors is an appropriate measure of improvement in accuracy. These values are in the last column of table 5. The most dramatic effect of adjustment is the 34 percent reduction in variance of sampling errors in the first test interval. Much of the benefit of making test-interval adjustments accrues through use of partial records in early lactation. Perhaps more management decisions are made in the early stages than at any other time.

The effects of all combinations of test-interval adjustments on bias and sampling error of lactation yield are shown in table 6. Nearly all the improvement in accuracy of estimating lactation yield can be attributed to adjustment of the first test interval. The sampling scheme used in this study did not include any unusually long test intervals such as may be due to missed milk weights or supervisors' vacations. The occurrence of unusually long intervals justifies adjustment of the second and last test intervals even though these adjustments add little to the accuracy of regular 30-day test intervals.

The average adjusted lactation yield is essentially free of bias. It is important to realize, however, that the adjusted NCDHIP estimate of yield for an individual cow may differ from the cow's actual yield. In two-thirds of all records, the NCDHIP estimate differs from actual yield by less than 250 lb. We can expect 5 percent of lactation records to be in error by more than 500 lb.

Table 4.--Bias in milk yield for first test interval by days in milk at first sample

Day of first sample	Lactation 1			Lactation ≥ 2		
	Actual	TIM	Bias	Actual	TIM	Bias
	Lb	Lb	Lb	Lb	Lb	Lb
12----------	363	482	119	568	716	148
18----------	614	765	151	937	1,134	197
24----------	878	1,051	173	1,317	1,546	229
30----------	1,146	1,350	204	1,714	1,971	257
36----------	1,419	1,642	223	2,115	2,372	257
42----------	1,696	1,907	211	2,511	2,751	240

Table 5.--Bias and sampling error in estimated milk yield for potentially biased test intervals computed without and with adjustment

Test intervals	Bias		Sampling error		Reduction in sampling variance
	Without adjustment	With adjustment	Without adjustment	With adjustment	
	Lb	Lb	Lb	Lb	Pct
First---------	176	-8	113	92	33.7
Second--------	-34	-2	78	77	2.5
Last----------	23	9	49	43	23.0

Table 6.--Bias and sampling error in estimating lactation milk yield when all combinations of test-interval adjustments are applied

Intervals adjusted	Bias	Sampling error	Reduction in sampling variance[1]
	Lb	Lb	Pct
None----------------	176	260	---
First (1)------------	-7	251	6.8
Second (2)---------	209	260	0
Last (L)------------	162	259	.8
1, 2----------------	25	253	5.3
1, L----------------	-22	250	7.5
2, L----------------	194	260	0
1, 2, L-------------	11	251	6.8

[1] The reduction in sampling variance is relative to the squared sampling error when no interval is adjusted.

Appendix

This section contains technical information on the development and evaluation of the test-interval factors.

Interval from calving to first sample day.--After the data for this research were collected, the definition for the first day of lactation was changed from the third day after calving to calving date. Under the new rule, milk weights for the first 3 days of lactation were required. They had not been recorded in the original data set.

A separate data set was compiled for the purpose of developing a procedure for estimating yield on days 1 to 3. Daily milk weights for the first 8 days of lactation were from 598 lactations that began over a 3-year period in the University of Wisconsin herd. Cows of the five major breeds were included. Calvings were supervised closely, and the calendar date of calving was known, even for calvings that occurred at night. Calves were removed from the dam without nursing. Cows were milked at the next regular milking after calving, and milk weights were recorded at each milking. Milking times were 4:00 a.m. and 3:00 p.m. Percentages of cows with none, one, or two milkings on calving date were 40, 49, or 11. Average total yield for days 1 to 3 was 67.8 lb, and standard deviation among cows was 30.0 lb.

Total yield for days 1 to 3 was regressed on various yields measured on days 4 to 8. Results were (1) estimates based on day 4 alone were more precise than on any other single day; (2) regression on total yield for days 4 to 8 was slightly less accurate than day 4 alone; (3) multiple regression on each of days 4 to 8 was only slightly more accurate than regression on day 4 alone; and (4) quadratic terms in these regressions were not significant.

It was concluded that yield on days 1 to 3 was best estimated by 1.7 times yield on day 4. The coefficient of determination was 65 percent and standard error of estimate was 17.8 lb. Component yields for days 1 to 3 were computed from the component percentage on day 4 and estimated milk yield for days 1 to 3.

Factors were developed from ratios as follows:

$$R_{T1j} = \frac{\sum_{i=1}^{T1} Y_{ij}}{T1(Y_{T1j})} = \frac{\text{Average daily yield for test interval}}{\text{Yield on first sample day}}$$

where R_{T1j} is ratio for cow j on day $T1$, $T1$ is days in milk at first sample after calving, and Y_{ij} is milk yield on day i for cow j. The set $T1 = 6, 7, 8, \ldots 39, 40, 42, 46, 50, \ldots 74, 78$ was used for each cow. The ratios were averaged over cows for each sample day within first and later lactation groups. Curve-fitting techniques were used to estimate and smooth the average ratios. Functions of the form

$$\hat{R}_{T1} = b_0 + b_1(\sqrt{T1}) + b_2(T1) + b_3(T1^2)$$

were found to fit the averages well. Values of the coefficients b_0, b_1, b_2, and b_3 are in table 7 for each trait and lactation group. Factors in table 1 were derived from these coefficients. Table 7 also shows the coefficients of determination for estimated and actual ratios.

Table 7.--Regression coefficients and coefficients of determination (R^2) for ratio factors in first test interval[1]

Yield trait	Lactation	Regression coefficients				
		b_0	b_1	b_2	b_3	R^2
Milk-------	1	0.605	0.0435	---	---	0.984
	≥2	.635	.0435	---	---	.990
Fat--------	1	.235	.239	-0.0225	0.000069	.946
	≥2	.476	.146	-.0115	.000038	.971
Protein----	1	.136	.316	-.0351	.000130	.964
	≥2	.177	.324	-.0366	.000141	.986
SNF-------	1	.342	.180	-.0173	.000066	.988
	≥2	.416	.167	-.0163	.000069	.996

[1] The form of the function is $\hat{R}_{T1} = b_0 + b_1(\sqrt{T1}) + b_2(T1) + b_3(T1^2)$ where $T1$ is day of first sample.

Intervals around the lactation peak.--Factors were developed from ratios as follows:

$$R_{T1,D,j} = \frac{2 \sum_{i=T1+1}^{T2} Y_{ij}}{D(Y_{T1\,j} + Y_{T2\,j})} = \frac{\text{Average daily yield for test interval}}{\text{Average yield for 2 sample days}}$$

where $R_{T1,D,j}$ is the ratio for cow j with the first sample on day $T1$ of lactation and D days in the test interval; $T2$ is days in milk on the second sample day; D is $T2$ minus $T1$; and $T1$ and Y_{ij} are as defined earlier. $R_{T1,D,j}$ was computed for all combinations of $T1 = 6, 7, 8, \ldots 26, 27, 30, 33, \ldots 42, 45$ and $D = 3, 6, 9, \ldots 72, 75$ for each cow in the data set. The ratios for each ($T1$, D) combination were averaged over all cows in each lactation group. Milk yield ratios were fitted and smoothed by the regression equations:

$$\text{Lactation 1:} \quad \hat{R}_{T1,D} = 0.998 + 1.23(T1^2) + 0.0113(D/T1)$$

$$\text{Lactation 2:} \quad \hat{R}_{T1,D} = 1.011 - 0.00042(T1) + 0.0109(D/T1)$$

Coefficients of determination were 0.982 and 0.978 for lactation groups 1 and 2. Milk factors in table 2 were computed from these functions using $T1 = 6, 9, 12, 18, 27$, and 36 and $D = 6, 15, 24, \ldots 69$.

Ratios for the component yields were too irregular to be fitted by regression. Factors in table 2 are the average ratios. Upon approval by the Committee on Standards for Estimating Yield and Other Performance Traits of Dairy Cattle Enrolled in NCDHIP, certain of the protein factors were adjusted upward to a value of 1.0. Protein ratios for lactation group 2 at $T1 = 8$ to 13 were less than 1.0, implying a lactation curve with two peaks. Such a phenomenon did not exist for the other traits and had not been observed in other data sets. Thus, the tampering seemed justified.

Interval from last sample to end of lactation.--The rate of decline in daily milk yield is nearly linear after the peak of lactation (fig. 1). Therefore, a purely geometrical approach was adopted in developing factors for the last test interval. Ratios of actual yield to TIM yield were not used.

Factors were derived as the ratio of the area (*G*) of a trapezoid that represents actual yield to the area (*F*) of a rectangle that represents yield estimated by TIM. The difference between these areas is the area (*H*) of a triangle that represents the bias in TIM yield. In figure 2, for the interval from 280 to 305 days, *H* is the cross-hatched area, *G* is the area under the curve, and *F* is the area enclosed by the dashed line, the sum of *G* and *H*.

Let *D* be number of days in test interval, *TL* be days in lactation at last sample, Y_{TL} be measured yield on last sample day, $R_{TL,D}$ be ratio factor, and *c* be rate of decline in daily yield, i.e., absolute value of regression of average daily yield on day of lactation. Then,

$$F = G + H$$

$$D(Y_{TL}) = D[Y_{TL} - \tfrac{1}{2}c(D)] + \tfrac{1}{2}c(D^2)$$

$$R_{TL,D} = \frac{G}{F} = \frac{D[Y_{TL} - \tfrac{1}{2}c(D)]}{D(Y_{TL})}$$

$$= 1 - \frac{\tfrac{1}{2}c(D)}{Y_{TL}} \qquad (1)$$

Two kinds of adjustment are possible:

(1) Additive: This results in the same amount of adjustment for all cows with the same *D* regardless of *TL*. Adjusted yield for cow *j* is

$$D(Y_{TLj})(R_{TL,D}) = D(Y_{TLj})\left(1 - \frac{\tfrac{1}{2}c(D)}{Y_{TLj}}\right)$$

$$= D(Y_{TLj}) - \tfrac{1}{2}c(D^2)$$

The adjustment is the area of the triangle (*H*).

(2) Multiplicative: The adjustment depends on the cow's level of production. In equation (1), replace Y_{TL} with $\overline{Y}_{TL} = \alpha - c(TL)$, the population average yield on day *TL*. Values of α and *c* were obtained by regression of average daily yield on day of lactation for days 151 to 300. Adjusted yield is

$$D(Y_{TLj})(R_{TL,D}) = D(Y_{TLj})\left(1 - \frac{\tfrac{1}{2}c(D)}{\overline{Y}_{TL}}\right)$$

$$= D(Y_{TLj}) - \left(\tfrac{1}{2}c(D^2)\,\frac{Y_{TLj}}{\overline{Y}_{TL}}\right)$$

The amount of adjustment is proportional to the ratio of the cow's sample-day yield to population average yield. The adjustment varies with TL because for a given D the ratio $G:F$ declines as TL increases.

Both methods were applied to each cow in the data set. Estimated yield was compared with actual yield for several combinations of TL and D. Multiplicative factors had slightly but consistently smaller biases than additive factors. In addition, sampling errors were smaller for multiplicative factors. The difference between methods was slight when D was small but increased as D increased. The difference between the methods did not vary with TL. Sampling errors for TL = 240 were typical and are shown in table 8.

Additive factors overadjusted cows with low yield and underadjusted high yielding cows. This suggests that multiplicative factors would be appropriate. Strangely, the multiplicative factors overcorrected at both low and high yields and undercorrected at intermediate levels. Perhaps adjustments of the form

$$\tfrac{1}{2}c(D^2)\left(\frac{Y_{TLj}}{\overline{Y}_{TL}}\right)^x$$

would be unbiased at all levels of production. It remains for future research to try this approach. Because of the advantage of smaller sampling errors demonstrated in these data, the multiplicative factors were adopted.

Factors in table 3 were computed from the function

$$1 - \frac{\tfrac{1}{2}c(D)}{\alpha - c(TL)}$$

using coefficients for α and c that are in table 9. Note that the function is linear with respect to D and that the slope varies with TL. Factors in table 3 were computed with TL = 95, 210, and 285 for lactation 1 and TL = 95, 160, 210, 245, 270, and 295 for lactation ≥ 2.

Table 8.--Sampling errors for estimates of milk yield in last test interval based on additive or multiplicative test-interval adjustments[1]

Days in test interval	Lactation 1 Average yield	Lactation 1 Sampling error Add.	Lactation 1 Sampling error Mult.	Lactation 1 Relative efficiency[2]	Lactation ≥ 2 Average yield	Lactation ≥ 2 Sampling error Add.	Lactation ≥ 2 Sampling error Mult.	Lactation ≥ 2 Relative efficiency[2]
	Lb	Lb	Lb		Lb	Lb	Lb	
5----	158	10.8	10.7	1.02	184	29.4	29.1	1.02
15----	469	34.3	33.8	1.03	540	90.5	88.2	1.05
25----	772	59.8	58.5	1.04	881	152.8	146.4	1.09
35----	1,066	87.0	84.6	1.06	1,204	217.4	204.9	1.13
45----	1,352	119.8	115.8	1.07	1,511	285.6	265.9	1.15
55----	1,626	157.9	152.1	1.08	1,800	358.0	329.5	1.18
65----	1,888	202.5	194.5	1.08	2,067	435.2	396.5	1.20

[1] Results are for test intervals beginning on day 240 of lactation and days in test interval ranging from 5 to 65.

[2] Additive sampling variance divided by multiplicative sampling variance.

Table 9.--Statistics from regression of average daily yield on day of lactation

Component	Lactation 1 α	Lactation 1 c	Lactation 1 SE_c[1]	Lactation 1 R^2	Lactation ≥ 2 α	Lactation ≥ 2 c	Lactation ≥ 2 SE_c[1]	Lactation ≥ 2 R^2
	Lb	Lb/day			Lb	Lb/day		
Milk------------	48.3	0.071	1.32	0.95	71.0	0.144	0.759	0.99
Fat-------------	2.03	.0025	.068	.89	2.78	.0052	.040	.99
Protein---------	1.67	.0019	.049	.90	2.39	.0045	.028	.99
SNF-------------	4.35	.0057	.150	.96	6.54	.0130	.081	.99

[1] Standard error of regression coefficient times 1,000.

FACTORS FOR ESTIMATING SAMPLE-DAY YIELD IN AM-PM SAMPLING PLANS

By G. E. Shook,[1] E. L. Jensen,[1] and F. N. Dickinson[2]

AM-PM sampling plans to reduce the labor of recordkeeping have been developed in the National Cooperative Dairy Herd Improvement Program (NCDHIP). These plans are called AM-PM plans because samples (and milk weights in most instances) are collected at only one milking per month instead of two. The sampled milking alternates morning and evening. When fewer farm visits are required, travel costs are reduced and work schedules and income are improved for supervisors. For all AM-PM plans, participants save expense, inconvenience, and milking time. On January 1, 1980, a total of 344,525 cows were in official and nonofficial AM-PM testing plans, representing 8.2 percent of all cows enrolled in the NCDHIP.

Cows do not produce equal quantities of milk and milk components in morning and evening milkings because of unequal daytime and nighttime milking intervals and different milk secretion rates between day and night. Therefore, sample-day yields usually cannot be estimated accurately by doubling the production from one milking. The purpose of this article is to describe factors for estimating 24-hour yields of milk and milk components from one sample-day milking. These factors were developed from lactation records with morning and evening milk weights for 305 days following calving. Some lactations included fat, protein, and solids-not-fat (SNF) yields for each milking throughout the lactation in addition to milk weights.

Data

Milk weights were available for 1,210 lactations from the Beltsville Agricultural Research Center and Illinois, Michigan, Nebraska, Pennsylvania, and Wisconsin Agricultural Experiment Station herds.[3] Of these, 966 could be used in this study because they had weights by individual milking and herd milking intervals. The five major dairy breeds were represented with 78 percent of the records from Holsteins. Milking intervals were regarded as the same for all records within a herd. Daytime milking intervals included in the data were 9.5, 10, 11, 11.5, and 12 hours.

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Fat and protein yields were from 151 lactations from the Michigan, Nebraska, and Wisconsin Agricultural Experiment Station herds. Holsteins accounted for 81 percent of these lactations, and the remainder were from Guernseys. Milking intervals were 10, 11, and 12 hours.

SNF yields were included for 78 lactations from the Michigan and Wisconsin Agricultural Experiment Station herds. Holsteins accounted for 63 percent of these lactations, and the remainder were from Guernseys. Milking intervals were 11 and 12 hours.

Analysis of Data

Statistical analyses of the data determined which of the characteristics required separate factors for adjusting AM-PM records. The characteristics studied were breed, milking interval, lactation number, month of lactation, and season of test.

Milking interval was the most important characteristic affecting adjustment factors. This was true for milk yield and component yields alike. Thus, separate factors were required for various milking intervals.

Breed, lactation number, and season of test were statistically significant sources of variation in some cases. However, the differences were less than 2 percent of the average production at a given milking interval for all classes. Most differences between classes were smaller than 1 percent. When differences between classes did occur, they were usually at the 9- or 10-hour milking intervals. It was concluded that one set of factors would be adequate for all breeds, lactation numbers, and seasons of test.

Results for month of lactation were inconclusive. Month of lactation was not statistically significant for any of the yield traits in lactations that included fat and protein yield. When all lactations with milk yield were studied, stage of lactation appeared to have an effect large enough to justify separate factors for each stage. There was no difference between stages at the 12-hour milking interval. Differences between stages became greater as the daytime interval became shorter. These results suggested that at shorter daytime milking intervals, the factors for adjusting evening yields should be larger in late lactation than in early lactation. Conversely, factors for adjusting morning yields should be smaller in late lactation than in early lactation. To simplify adjustment procedures and to make milk-yield factors consistent with those for component yields, we developed one set of factors for all stages of lactation.

Comparison of factors for the four yield traits indicated milk-yield factors could be applied to protein and SNF yields, but separate factors were required for fat yield. Fat test varies between morning and evening milkings, indicating the need for separate factors. Morning and evening tests for protein and SNF were nearly identical so that AM-PM factors for milk yield can also be used for the nonfat solids.

Development of Factors

Letting A and P represent yields of morning and evening milkings, respectively, $(A + P)$ is daily yield. The portion of daily yield produced in the evening is

$$PMP = \frac{P}{A + P}$$

The portion of daily yield produced in the morning is

$$AMP = \frac{A}{A + P} = 1 - PMP$$

Factors for estimating sample-day yield from evening yield (PMF) were derived as

$$PMF = \frac{1}{PMP}$$

and factors from morning yield were derived as

$$AMF = \frac{1}{AMP} = \frac{1}{1 - PMP} = \frac{PMF}{PMF - 1}$$

These relationships apply to yields of the milk components as well as milk yield.

Average PMP was calculated for each milking interval for milk and fat yield. A quadratic regression of average PMP on milking interval was computed to smooth the points and to provide a value for the daytime interval of 10.5 hours, which was not represented in the data. PMP values computed from the regression equation were used to compute the factors (PMF, AMF). Linear instead of quadratic regression was used to estimate PMP values for the daytime intervals of 9, 12.5, and 13 hours, which were outside the range of the data.

Applying the Factors

Separate factors for milk and fat for estimating sample-day yield from either morning or evening yield are in table 1. The milk yield factors should be used for protein and SNF yields. Milking intervals are given in increments of one-half hour. Daytime interval is hours from beginning of morning milking to beginning of evening milking. When using the table, milking interval should be rounded to the nearest one-half hour, e.g., use the 11.5-hour factors for intervals ranging from 11 hours 15 minutes through 11 hours 44 minutes.

To estimate daily yield, multiply the evening yield by the appropriate PM factor or multiply the morning yield by the appropriate AM factor. Consider a cow that produced 40 lb of milk with 3.8 percent fat on a morning milking after a 13-hour nighttime interval. Her fat yield for that milking would be (40 lb)(0.038) = 1.52 lb. The factors from table 1 in this case are 1.82 for milk and 1.91 for fat yield. Estimated 24-hour yield on the test day is (40 lb)(1.82) = 72.8 lb milk and (1.52 lb)(1.91) = 2.90 lb fat. Estimated fat percentage for this cow is (2.90 lb/72.8 lb)(100) = 4.0 percent. Estimated sample-day yield obtained in this way may be used in computing test-interval and lactation credits as though milk weights and samples were from both milkings. (See page 2 for method of computation.) In plans where fat percentage is from one milking and milk weights are measured at two milkings, fat production is computed from the weight at the sampled milking only.

Note that the fat test for sample-day yield was higher than that measured in the morning milking in the example because morning fat tests are typically lower than evening fat tests. The effect of the factors for milk and fat yield on fat test is shown in table 2.

Table 1.--Factors for estimating sample-day yield from evening or morning milking

Daytime interval (hr)[1]	PM factor		Nighttime interval (hr)[1]	AM factor	
	Milk yield[2]	Fat yield		Milk yield[2]	Fat yield
9.0	2.58	2.19	15.0	1.63	1.84
9.5	2.49	2.17	14.5	1.67	1.85
10.0	2.40	2.16	14.0	1.72	1.86
10.5	2.31	2.14	13.5	1.77	1.88
11.0	2.21	2.10	13.0	1.82	1.91
11.5	2.12	2.05	12.5	1.89	1.95
12.0	2.03	2.00	12.0	1.97	2.00
12.5	1.94	1.94	11.5	2.06	2.06
13.0	1.86	1.89	11.0	2.17	2.13

[1] For an interval of 15 min less than the value to 14 min greater, use the factors for that interval.

[2] Milk-yield factors are appropriate for protein and solids-not-fat yields.

Table 2.--Daily fat test as a percentage of evening or morning fat test at various milking intervals. Values are based on the adjustment factors in table 1

Daytime interval	$\frac{\text{Daily test}}{\text{PM test}}$	Nighttime interval	$\frac{\text{Daily test}}{\text{AM test}}$
Hr	Pct	Hr	Pct
9.0	84.9	15.0	112.7
9.5	87.4	14.5	110.7
10.0	90.1	14.0	108.6
10.5	92.7	13.5	106.4
11.0	95.0	13.0	104.6
11.5	96.9	12.5	102.9
12.0	98.6	12.0	101.4
12.5	100.0	11.5	100.0
13.0	101.7	11.0	98.1

Actual production was computed from daily milk weights for all 966 milk production records and compared with yields estimated by procedures used in the NCDHIP. Test intervals were simulated averaging 30 days in length and ranging from 26 to 34 days. The milking interval for the particular herd was used. Test-interval adjustments shown in the previous article were used. Bias is the average estimated yield minus the average actual yield and measures the average amount by which the sampling plan overestimates or underestimates actual production. Sampling error is the standard deviation of difference between actual yield and yield estimated under the sampling plan.

Bias and sampling error of AM-PM sampling are shown in table 3. Results for records in which a cow's first sample is in the morning are given separately from those with the first sample in the evening. Values are listed for lactation-to-date milk records with and without adjustment for milking interval after each of the first three test intervals and for total lactation.

Biases were large in early lactation without adjustment. The more unequal the day and night milking interval, the greater the bias for any particular test interval. Averaged over the daily milking intervals represented in the data, a cow's yield for the first test interval would be 147 lb higher with a morning test than with an evening test. After adjustment, the biases were small at all stages of lactation. Biases in lactation yield were small with or without adjustment.

Sampling errors increase as lactation progresses because average yield increases. In general, sampling errors for records with the first sample in the evening were smaller than those with the first sample in the morning.

The improvement in accuracy of sampling plans that is attributable to adjustment can be measured by the reduction in sampling variance (the square of sampling error) due to adjustment. This reduction is expressed as a percentage of sampling variance without adjustment. These percentages are in the last column of table 3. The factors improve the accuracy of records that begin with the morning test more than records that begin with the evening test. Also, the improvement is greater in early lactation than in late or total lactation. Most management decisions are based on early lactation records. Therefore, most of the benefit from adjusting AM-PM records is in the critical, early part of lactation.

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Table 3.--Bias and sampling error of milk yield from alternate AM-PM sampling plans without or with adjustment for milking interval

Test intervals	First sample	Bias: Without adjustment	Bias: With adjustment	Sampling error: Without adjustment	Sampling error: With adjustment	Reduction in sampling variance due to adjustment
		Lb	Lb	Lb	Lb	Pct
1-------	AM----	66	-11	135	112	31.2
	PM----	-81	-3	123	117	9.5
1, 2----	AM----	56	-15	193	174	18.7
	PM----	-71	-2	176	176	0
1, 2, 3-	AM----	52	-16	217	204	11.6
	PM----	-72	-2	212	211	.9
All-----	AM----	34	4	372	367	2.7
	PM----	-13	21	346	347	-.6